

**Costa Rica Virtual Corridor Project: Forest
Connectivity**

ENVS 4520: GIS II

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1. Introduction

Costa Rica, located formally in Central-America, connects North and South America. True to its Spanish name “rich coast”, it has fertile land. Costa Rica has a very rich diversity of plant and animal species, as a chain of rainforests are its fundamental land cover. However, Costa Rica is facing environmental degradation similar to other regions in the world because of ongoing development and urbanization. This has started a number of conservation projects, and COBAS “Virtual Corridor” is just one of them. COBAS is a tool which provides datasets to construct and manipulate future developments in Rio Peñas Blancas.

Professor Felipe Montoya has presented York University’s Las Nubes ecological corridor forest fragmentation as an problem that must be solved. Roads have fragmented the ecological corridor, with a potential for hydro-dams also being installed for production of electricity. Professor Montoya would like to prevent fragmentation by determining which parcels of land are most important for its uninterrupted connectivity. Sufficient connectivity would prevent habitat fragmentation, which is deadly for the ecosystem. Such connectivity could be analyzed by using GIS software. Previous studies have already proven that GIS could be efficient on providing information of land use and land cover (Weng, 2002), as such, we will use GIS to study forest connectivity. Our group will set out to analyze and quantify which parts of the Las Nubes ecological corridor is most important to the connectivity of the forest. Our group hopes to present data, which can be used to further enhance connectivity of the forest to promote the health of the ecosystem.

2. Hypothesis

Our group has already taken into consideration the use of "zonal statistics" to assign parameters/values on forest fragments based on their individual attributes. The second part of the assignment would be to preserve forested areas which are already present within the study area. Sections of fragmented forest would benefit from increased connectivity to neighbouring fragments; expanding forested habitat. Professor Montoya mentioned using thin strips of forested land to connect forest fragments giving us more options for enhancing connectivity. For the final analysis roads will be taken into consideration as they cannot be obstructed with connecting fragments.

3. Study Area

The study area for this project is the COBAS “Virtual Corridor” conservation area in Costa Rica. The study would be conducted within the area of “Virtual Corridor”, and all layers and analysis would be generated within this area. At first, a screenshot was taken from the COBAS website of the “Virtual Corridor” to begin our study, as there was a lack of efficient datasets. However, this method was only used while there was no sufficient datasets, which was later solved after locating original datasets in the website.

On the other hand, WGS 1984/UTM 17N is the coordinate reference system (CRS) of this project, and it is Mercator conformal projection. In detail, a secant

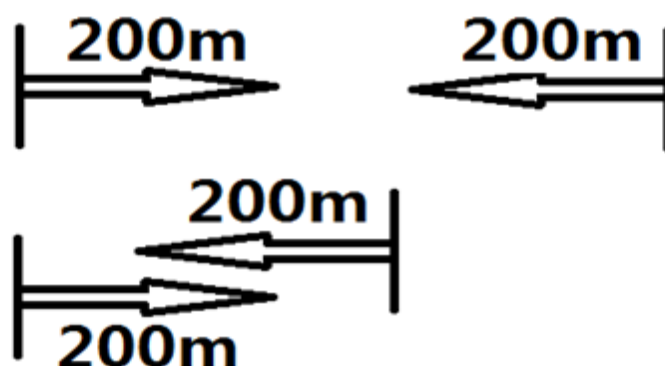
transverse Mercator projection in UTM zone 17 in the northern hemisphere.

4. Methods

4.1: Recommended reforestation zones between patches

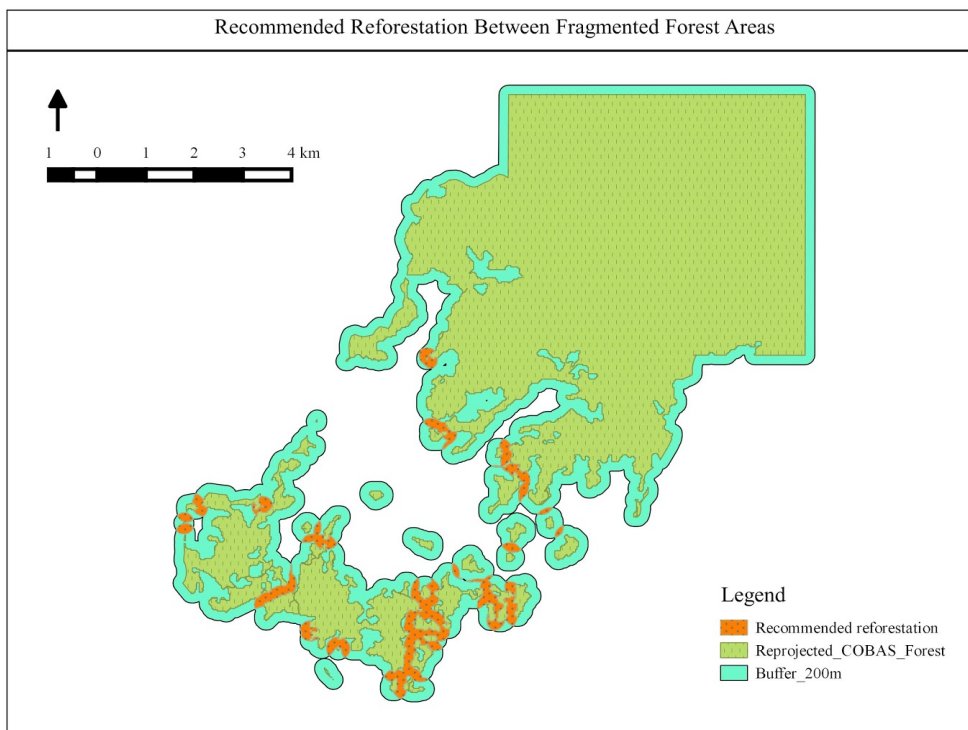
Recommended reforestation zones exist between some forest patches, under the condition of their fragmentation. Detection of these areas would contribute on making guidelines of reforestation. It would be much more efficient economically and ecologically to reforest in detected areas. For example, 400 meter as the longest distance to be reforested.

It was started by assuming 400 meter is the maximum distance that reforestation could be implemented. Patches with distances greater than 400 meter would not be reconnected due to the potential unacceptable cost. Then, we divide it into two parts as we need to convert one-direction into two-directions, and each has 200 meter (Figure 1). This number would be used to buffer the forest polygons. If buffer zones are intersected, it means there are regions worthy reforesting. A further modification on resulted intersections would be required to remove redundant information, which involves modification on attribute table and dissolving. Finally, overlaps with initial forest areas have been removed from the result.



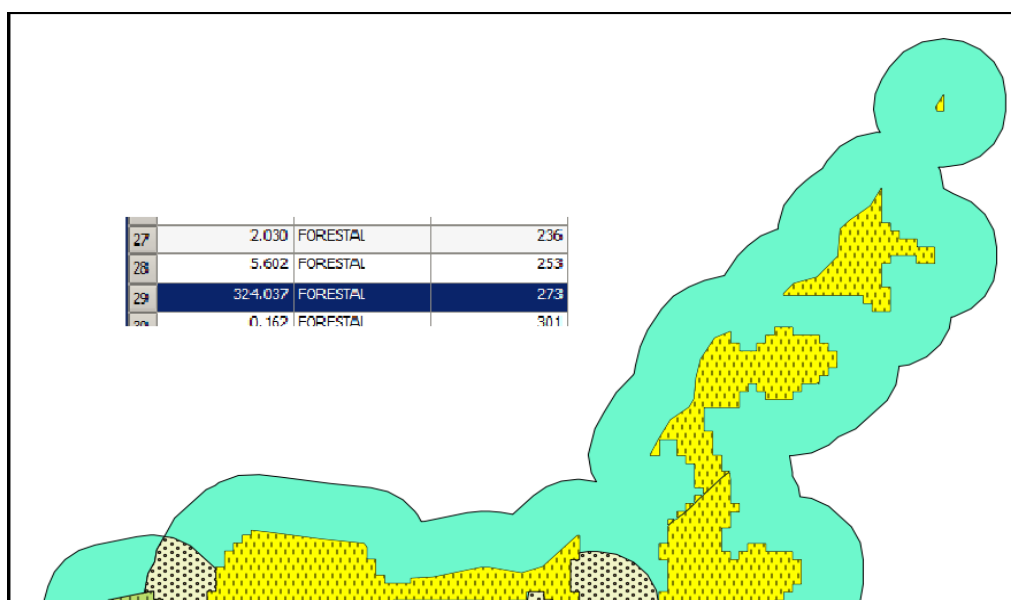
(Figure 1): Disconnection and intersection.

As a result of this method, a polygon layer would be produced (Figure 2). This layer would indicate recommended reforestation zones all over the region that are suitable for regenerating connectivity by reforestation. It could be seen most of fragmented forest areas could be re-connected in an acceptable way. And if these areas are blocked, or forest near them being degraded further, or any other cases occur, a further damage/disconnectivity would occur. However, there would be limitations on this method. Firstly, some recommended zones would not touch the initial fragmented forest areas, which means these places would be very close to the deadline - 400 meter. Secondly, there would be isolated forest areas cannot be re-connected in this normal method, which require other methods for regenerating connectivity.



(Figure 2): Recommended reforestation zones between fragmented forest areas.

On the other hand, it is found that recommended reforestation zones are not generated between polygons that meet the criteria in some places of the study area (Figure 3). Theoretically, there should be recommended reforestation zones generated in any places that have a distance shorter than 400 meter, but it actually did not happen. Later, it was found that these ‘separated’ polygons are actually a same polygon, for example, polygon 273 highlighted in Figure 3. It seems this phenomenon is actually caused by a cut that had been done by using the border of “Virtual Corridor” project, which makes some part of the polygon being removed and results in ‘separated’ polygons. Generally, it means these ‘separated’ forest patches are actually connected in the real world.



(Figure 3): ‘Separated’ forest patches.

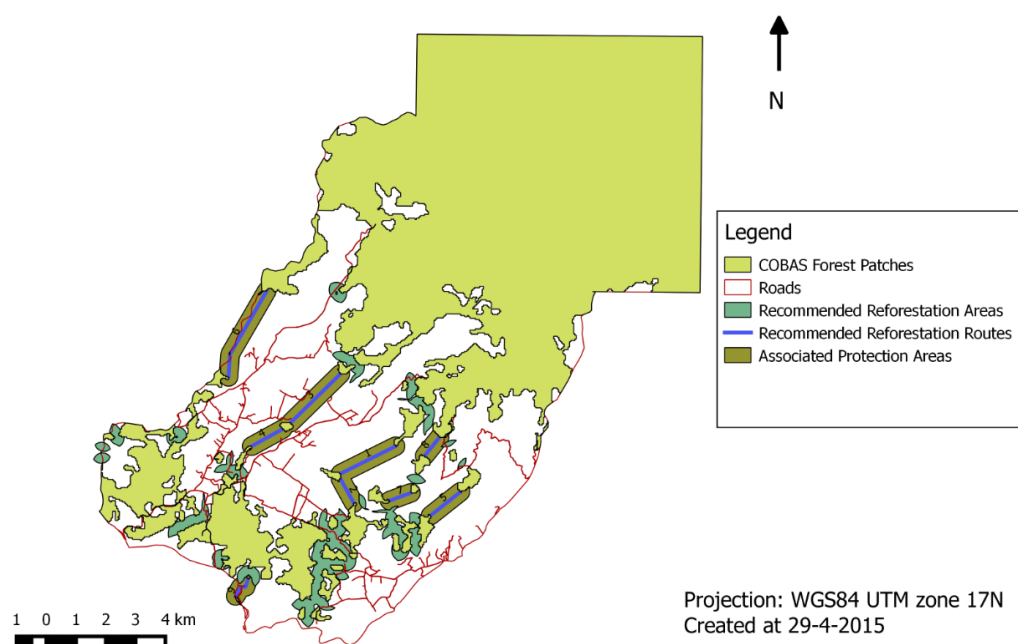
4.2: Recommended Reforestation Routes and Associated Protection Areas

The objective of this part is to further enhance the interconnectivity between different forest patches identified within the COBAS buffer zone. As shown in the map, two major forest patches can be observed at the northern and southern parts of the buffer zone. However, there are a number of isolated forest patches found within the central area. Therefore, we hope that these isolated patches can be connected to one or both of these major patches. Besides, connecting these two major patches together will also create a better environment for species movement.

According to Professor Felipe Montoya, connectivity refers to the degree to which the landscape facilitates or impedes species movement based on forest availability and distance between patches. Connectivity between patches can be enhanced by the plantation of a line of trees as long as the crowns and shadows provided are large enough for species movement. Inspired by his explanations, we try to increase the connectivity between patches, especially the isolate ones, by designing a reforestation route (i.e. a line of trees). The design of routes follows a few conditions, including it cannot intersect with existing roads, and it should be as short as possible in order to ensure its cost efficiency.

In this part, layers of COBAS forest patches, recommended reforestation areas, and roads are included at the first place. Then, a new vector layer (i.e. line), named 'Recommended reforestation routes', is created. 9 different lines/routes are drawn by editing tool. Any intersection with existing roads should be avoided while the distances should be kept as short as possible. After that, the routes are buffered by 200m (please refer to the aforementioned assumption in 4.1) to create a protection area for each designated route, named 'Associated protection areas'. Figure 4 is the exported map. And Figure 5 presents the total length of 9 routes and the total associated protection area.

Recommended Reforestation Routes and Associated Protection Areas

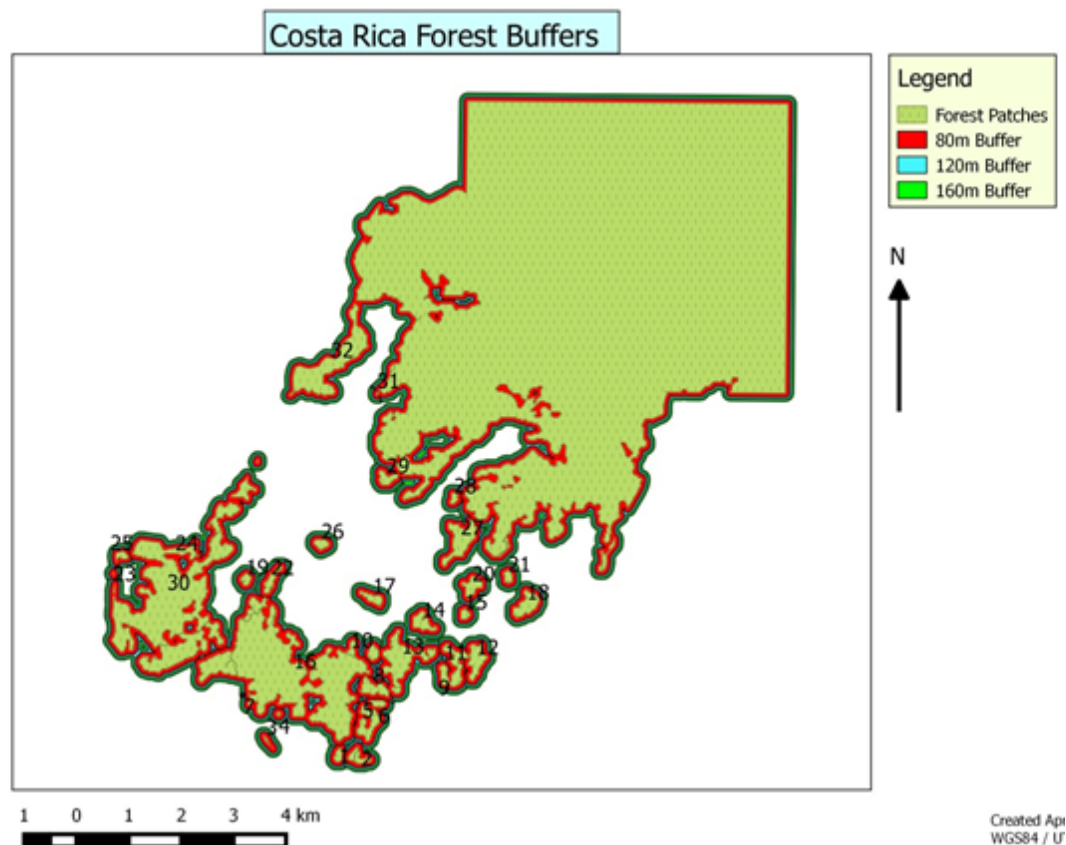


(Figure 4): Recommended reforestation routes and associated protection areas

Recommended Reforestation Routes (NO.)	LENGTH (m)	
1	1315.29717	
2	588.7944179	
3	1492.520669	
4	758.6496851	
5	818.6463301	
6	2055.475193	
7	487.7644413	
8	511.3915079	
9	505.7392477	
TOTAL	8534.278662	
Associated Protection Areas	AREA (m ²)	PERIMETER (m)
TOTAL	4394796.819	26414.20573

(Figure 5): Total length and area of recommended reforestation routes and associated protection area


4.3: Analysis of Buffer Efficiency



(Figure 6): Buffers of 80, 120, and 160 meters.

The goal of this analysis is to determine which buffer length (80m, 120m, 160m) is most efficient in maintaining forest connectivity. Efficiency is determined by the number of forest patches each buffer is able to connect; larger buffers would connect more patches, but may be inefficient compared to smaller buffers. It wouldn't be necessary to increase the buffer size of reforested areas if there will only be a marginal increase in connected forest patches. Cost creates a practical barrier to how large reforestation zones can be and this will help budget the project while preserving connectivity. During this step perimeter and area data was added to the attribute table for further quantitative analysis (figure 1). Roads create barriers for connectivity and cannot be reforested over. This is complicated further by no available data to classify the type of roads running through the corridor. Connectivity is maintained as long as the tree canopy is connected; smaller roads and trails would still allow for connectivity even with a path present. With no data to define the road type, wide and narrow roads cannot be discerned from each other. External software and plugins were considered for automated analysis; FRAGSTATS required raster data in order to run. Raster data of our study area had heavy cloud coverage and would reduce the accuracy of FRAGSTATS.

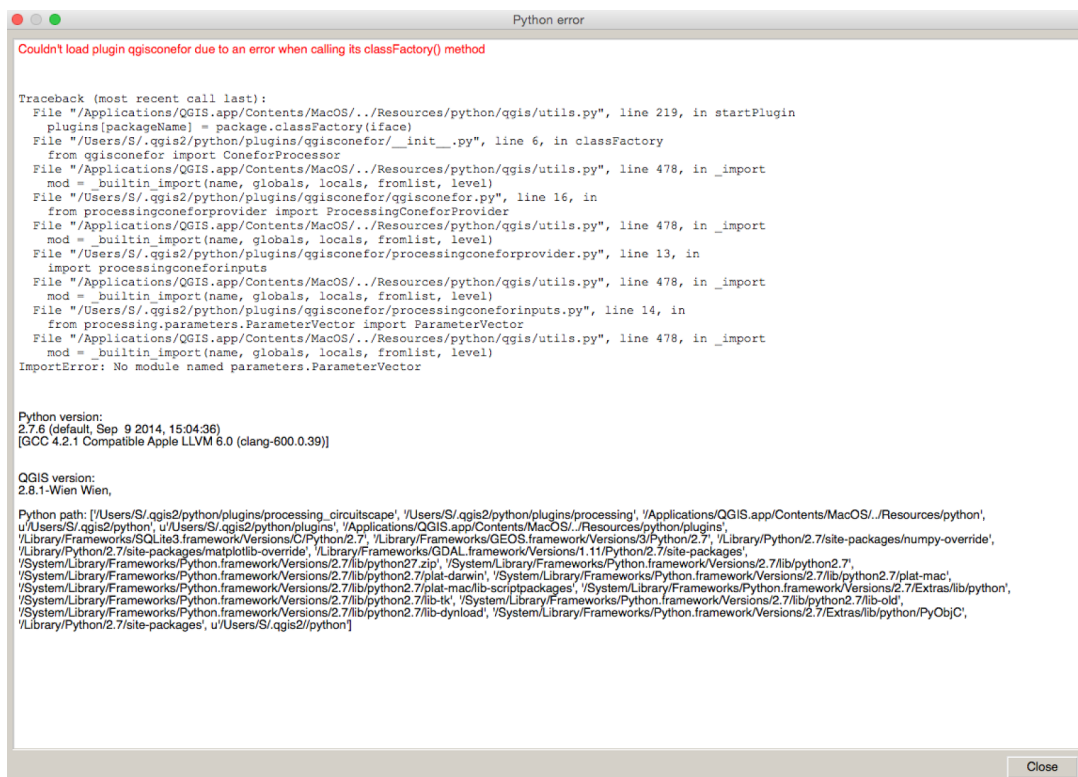
Q Attribute table - Reprojected_COBAS_Forest :: Features total: 32, filtered: 32, selected: 0



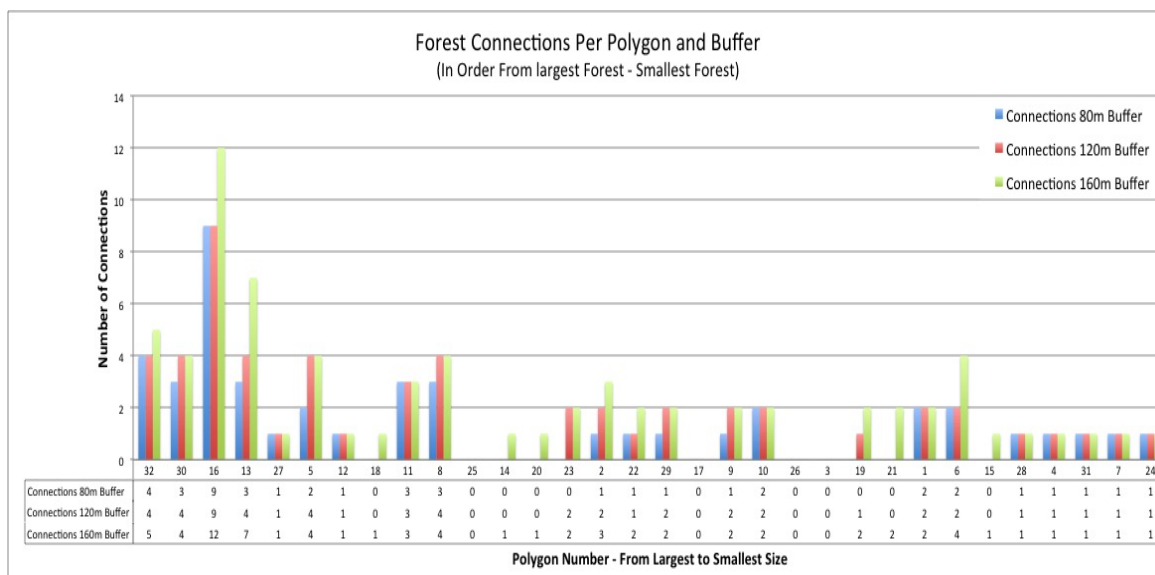
	HECTARES	COBERTURA	Perimeter	Area	ID
0	2.842	FORESTAL	798	28456	1
1	5.846	FORESTAL	2136	57506	2
2	3.491	FORESTAL	622	5265	3
3	0.406	FORESTAL	342	4065	4
4	13.640	FORESTAL	3474	135960	5
5	2.842	FORESTAL	798	28456	6
6	0.081	FORESTAL	114	813	7
7	9.987	FORESTAL	2110	100004	8
8	4.547	FORESTAL	1084	45530	9
9	4.222	FORESTAL	969	42278	10
10	13.153	FORESTAL	3308	131710	11
11	13.234	FORESTAL	2566	132522	12
12	36.212	FORESTAL	6518	361567	13
13	8.444	FORESTAL	1996	84556	14
14	2.517	FORESTAL	741	25204	15
15	308.609	FORESTAL	28516	3079683	16
16	5.115	FORESTAL	1426	51222	17
17	13.234	FORESTAL	2224	132521	18
18	3.085	FORESTAL	1065	30471	19
19	8.282	FORESTAL	1711	82929	20
20	3.004	FORESTAL	855	30082	21
21	5.846	FORESTAL	2228	57615	22
22	6.008	FORESTAL	113	368	23
23	0.081	FORESTAL	114	813	24
24	8.850	FORESTAL	895	24972	25
25	3.816	FORESTAL	969	38214	26
26	22.572	FORESTAL	3593	226024	27
27	2.030	FORESTAL	769	20228	28
28	5.602	FORESTAL	1483	56101	29
29	324.037	FORESTAL	33856	2752242	30
30	0.162	FORESTAL	171	1626	31
31	798343.406	FORESTAL	76124	47954927	32

(Figure 7): ID, Area, Perimeter added to forest patches

We had also considered the use of a plugin to QGIS which is called Conefor. Conefor would have helped analyze and determine which patches of land were most efficient to connect, and give a complete analysis of how connected the land is now. After download and installation of Conefor, we were still not successful at running the plugin due to QGIS errors as seen below. After receiving this error and determined to use Conefor for some sort of analysis, we decided to have it installed on a York University computer, using Esri ArcMap. The installation successful here, although after hours of reading the program manual, it was still very difficult for us to figure out how to run the analysis. There were many trial and errors, and still unsuccessful at using Conefor.



(Figure 8): Error message in QGIS regarding Conefor



(Figure 9): Graph comparing forest plot buffer connections - ordered by patch size - largest to smallest

We continued to use the method we developed in stage 2, that is, using excel to present the forest patched in an organized manner, determining most efficient linkages. The graph below shows all the polygons, numbered from 1-32. These polygons are ordered from largest forest size, to smallest for quick visual analysis. we can see that indeed, as described above, the largest patches have the most connections. However, even then, we can see that between the large patches, the third patch, 16, hold the most net connections. We can also see that polygon 18, although

is amongst the midsize plots, does not hold any connections through the 80m and 120m buffers, and only has one connection at 160m buffer.

Polygon #	HECTARES	Perimeter	Area	Connections 80m	Connections 120m	Connections 160m
32	798343.406	76124	47954927	4	4	5
30	324.037	33856	2752242	3	4	4
16	308.609	28516	3079683	9	9	12
13	36.212	6518	361567	3	4	7
27	22.572	3593	226024	1	1	1
5	13.64	3474	135960	2	4	4
12	13.234	2566	132522	1	1	1
18	13.234	2224	132521	0	0	1
11	13.153	3308	131710	3	3	3
8	9.987	2110	100004	3	4	4
25	8.85	895	24972	0	0	0
14	8.444	1996	84556	0	0	1
20	8.282	1711	82929	0	0	1
23	6.008	113	368	0	2	2
2	5.846	2136	57506	1	2	3
22	5.846	2228	57615	1	1	2
29	5.602	1483	56101	1	2	2
17	5.115	1426	51222	0	0	0
9	4.547	1084	45530	1	2	2
10	4.222	969	42278	2	2	2
26	3.816	969	38214	0	0	0
3	3.491	622	5265	0	0	0
19	3.085	1065	30471	0	1	2
21	3.004	855	30082	0	0	2
1	2.842	798	28456	2	2	2
6	2.842	798	28456	2	2	4
15	2.517	741	25204	0	0	1
28	2.03	769	20228	1	1	1
4	0.406	342	4065	1	1	1
31	0.162	171	1626	1	1	1
7	0.081	114	813	1	1	1
24	0.081	114	813	1	1	1
Total Connections				44	55	73
Primary Connections				44	11	18

(Figure 10): Spreadsheet of forest plot buffer connections - ordered by patch size - largest to smallest. Red represents fewest connections and green represents a higher number of connections.

Here we can see that a 80m buffer creates 44 connections. This is huge compared to the ladder buffers of 120m, and 160m. Thus, a buffer of 80m would yield the most connections. However, not all plots are close enough to create a connection at a 80m buffer, for example polygon #'s 18, 25, 14, 20, 23, 17, 26, 3, 19, 21, and 6 (all items shown in red). Furthermore, some plots are not close enough to create connections even at 160m, such as polygon #'s 17, 26, and 3. These plots are isolated, and must be patched accordly so that animals from these regions can spread. These animals are at higher risk due to their isolation; also considering that they are not amongst the large parcels of land, this is an increase of risk to them.

5. Conclusion

Connectivity of the forest has been restored in this project. Recommended reforestation zones have been indicated between most of fragmented patches, but there are still some isolated ones that cannot be connected by this method. Another method of creating reforestation routes is then made, and all patches are eventually connected. On the other hand, analysis of maintaining current forest connectivity is made, as further degradation is undesired.

However, besides the successful results generated, there are issues identified in this project. The greatest one is the lack of sufficient data, which results in the great difficulty of doing GIS analysis in this region. New datasets are suggested to be made, in case there will be other studies in the future.

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